TRANSMISSION EXPERIMENTS INVOLVING POSSIBLE INSECT VECTORS OF THE VIRUS, *MARMOR VIRGATUM* VAR. *TYPICUM* McKINNEY, WHICH CAUSES WHEAT YELLOW STREAK-MOSAIC

by

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B. S., Kansas State College
of Agriculture and Applied Science, 1950

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology, and
Department of Botany and Plant Pathology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1951

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INTRODUCTION

Wheat mosaic, although it was first observed in Kansas in 1929, has only recently become recognized as an important factor in the production of wheat in the western one-third of the state. The disease was particularly wide spread and severe in 1949, and serious damage occurred again over wide areas in several Western Kansas counties in 1951. It was estimated that the disease caused a loss of 15,500,000 bushels to the 1949 crop. (Hansing et. al., 1949.)

In view of the economic importance of wheat mosaic in Kansas and the lack of evidence concerning the natural spread of the disease, it seemed important to study the possibility of insect transmission.

The purpose of this work was to determine whether any insects were vectors of the causative virus and to provide information about the insects that are not vectors under the conditions of the experiments.

REVIEW OF THE LITERATURE

Mosaics of wheat occur in many widely separated and varied regions of the world, and are apparently caused by several distinctly different viruses. In the United States, such diseases have been reported from Kansas, Nebraska, Colorado, Oklahoma, Texas, South Dakota, Illinois, Indiana, Maryland, Virginia, and North Carolina. Outside of the United States, wheat mosaic has been described from Russia (Zazhurilo and Sitnikova, 1939), Japan (Wada and Fukano, 1937), and Egypt (Melchers, 1931).

The wheat mosaics which occur in the eastern part of the United States are known to be spread by means of infested soil. (McKinney, 1923, 1925). The wheat mosaics which occur in Russia are known to overwinter in specific insect vectors. One of these viruses is transmitted to healthy wheat plants by a leafhopper, Psammotettix striatus (L.) (Zazhurilo and Sitnikova, 1940), and a distinctly different virus is transmitted by a Fulgorid, Delphax striatella (Fall) (Sukhov and Petlyuk, 1940).

Unlike the wheat mosaics of the Eastern United States and Russia, the method of transmission of the wheat mosaic which occurs in Western Kansas is unknown. Since the virus has been demonstrated to be neither soil-borne (McKinney, 1937) nor seed-borne (Atkinson, 1949; Haskell and Wood, 1923), it appears most likely that some insects must serve as vectors in nature.

Several reports have suggested that an aphid is a vector. According to Haskell and Wood (1923) Peltier at Lincoln, Nebraska, first reported the transfer of a wheat mosaic virus by means of an unidentified aphid. He transferred aphids from infected wheat plants in the field to young healthy corn plants in the greenhouse. A slight infection was produced on one plant. Later McKinney (1937) transmitted one of the wheat mosaics collected at Salina, Kansas, by means of an unidentified aphid. The virus was either Marmor virgatum var. typicum McK. or M. virgatum var. viride McK. The unidentified aphids were present on infected wheat plants shipped in the late spring to McKinney at Arlington Farm in Virginia from Kansas. McKinney transferred the aphids to healthy wheat plants, for feeding, and one plant developed mosaic.

A more positive statement was made by Atkinson (1949) concerning the transmission of wheat mosaic in Colorado by means of the aphid, Toxoptera graminum (Rond.). In regard to this Atkinson (1949) stated,

> In the greenhouse, western wheat mosaic was transmitted by the grain aphid, Toxopetera gramineum (sic.). Single viruliferous aphids were isolated and implanted on pots of 10 healthy wheat plants. In every pot, 30 to 50 per cent of the plants had mosaic symptoms. Non viruliferous aphids failed to produce symptoms of mosaic although they were allowed to feed on the wheat until the plants died.

Atkinson does not give the conditions of his experiments, and apparently no one has ever been able to duplicate them. At least 25 experiments using T. graminum and an additional 60 using 5 other species of aphids were made at Manhattan, Kansas, by Dr. R. H. Painter and Dr. Hurley Fellows during the fall and winter of 1949. No transmission of the virus occurred in any of these experiments (unpublished report).

It would seem unlikely that T. graminum could serve as an efficient vector of a virus since it causes such a violent reaction in the plant on which it feeds; it was definitely proved to be a vector of sugar cane mosaic by Ingram and Summers (1938). They gave it an efficiency rating of 12 per cent after it had transmitted the virus 21 times out of 172 trials.

Johnson (1945) tested several insects for the possibility that they might transmit the soil-borne wheat mosaic virus, *Marmor tritici* McK. The insects that he worked with were *Psammotettix striatus* (L.), *Agalia sanguinolenta* Prov., *Agalia constricta* (Van D.), *Delphacodes campestris* (Van D.), and *Toxoptera graminum* (Rond.), but in no case did he find that any of the insects transmitted the virus. It seems possible that no insect vectors exist for this virus since it readily passes in nature in infested soil.

The Russians have apparently made considerable progress toward the complete understanding of how the wheat mosaics in Russia are transmitted. They not only have reported the specific vectors involved, but have determined many of the interrelationships between the viruses, their vectors and host plants. (Sukhov and Sukhova, 1940; Zazhurilo and Sitnikova, 1941).

The wheat mosaics in Russia are unique, as far as wheat mosaics are concerned, in that they can not be transmitted by the expressed juice from infected plants. Considering this difference, they may not be closely related to any of the wheat mosaics which are known to occur in the United States. Oman

(1949) stated that if the mosaic of winter wheat in Russia is a true mosaic, its transmission by a leafhopper is unusual.

MATERIALS AND METHODS

Materials

Virus. The virus used in this study is commonly known as Wheat Yellow Streak-Mosaic virus or Wheat Virus 7 McKinney. The scientific name applied to it is *Marmor virgatum* var. *typicum* McK. It was isolated from wheat collected at Salina, Kansas, in 1933 and has shown no material loss in virulence in the past 18 years.

In regard to the host range and physical properties McKinney (1944) stated that the virus induces typical chlorotic mottling, streaking, and dwarfing in the following hosts: *Triticum aestivum* L., *T. timopheevi* Zhuk., *T. turgidum* L., *T. durum* Desf., *T. spelta* L., *T. dicoccum* Schrank, *T. polonicum* L., *T. monococcum* L., *Hordeum vulgare* L., *Avena byzantina* C. Koch, *A. sativa* L., *A. sativa* var. *orientalis* (Schreb.), *A. brevis* Roth, *A. strigosa* Schreb., and *Zea mays* L.

The physical properties given showed that the symptoms were expressed over a relatively wide range of temperatures, from 15.6° C. to summer temperatures, apparently depending largely on the optimum requirements for the host. The virus is inactivated in plant juice near 55° C. in 10 minutes, after about 7 months in tissue frozen near -17° C. and after 34 to 40 days in dry tissue at room temperature. The dilution-end-point for the virus is near 5000 X.

The only known way in which this virus is readily transmitted is by inoculation with juice from infected plants. In these experiments the inoculum was prepared by extracting juice from the leaves of infected plants. The juice was then diluted with water and mixed with carborundum dust. Inoculation was accomplished by gently rubbing the leaves between an index finger and thumb which had been dipped into the inoculum.

Insects. The only insects used in these experiments were those which were known to feed on wheat plants. The number of different species of insects, both adult and immature, known to feed on wheat is large enough so that all of them could not be used.

Since the insects bearing piercing and sucking type mouth parts have most often been found to be the vectors of viruses, the emphasis in these experiments was primarily on those insects which feed on wheat through piercing and sucking type mouth parts.

Plants. Westar wheat is particularly susceptible to the mosaic virus. It was the only variety of wheat used in the transmission experiments involving insects.

Healthy and infected plants of various ages were made available through weekly plantings. The infected plants were obtained by inoculating the young wheat seedlings with the expressed juice from infected plants using the carborundum-wiping method.

Greenhouses. One greenhouse was used only for the insect transmission work. In this house, the plants were maintained under cages at all times.

The plants used in each experiment were moved to a second greenhouse for observation just as soon as the insects were dead or removed from the plants. The plants were also maintained in this greenhouse before they were used in the experiments. This house was not screened and, during the warm months when the windows were open, it afforded almost no protection against contamination from insects outside of the experiment.

The daily temperature fluctuated greatly but averaged about 75° F. during the winter months. In the spring and fall months temperatures during the day were often around 100° F. even though the houses were heavily shaded with white wash. A high humidity was maintained by keeping the benches and floor moistened.

Cages. The field cages were of two sizes as may be seen in Plate I. The dimensions of the larger cage were 24 x 20 x 38 inches as compared with 24 x 18 x 18 inches for the smaller cage. The smaller cage was the more practical of the two sizes for this work. The main features of the cages were the wood frame covered with a 36 x 36 mesh "Lumite" screen, the wide boards for the base to facilitate setting the cage in the ground, and the removable top. All joints were filled with strips of cheese cloth and securely clinched with screws.

The cages used in the greenhouse were mainly of two types.

The cage used to cover several wheat plants in a 6 inch pot (Plate II, Fig. 1) was approximately 5 inches in diameter and 13 inches long. The main features of the cage were the metal frame covered with 36 x 36 mesh "Lumite" screen, the wide band of metal forming the base to facilitate setting the cage in the soil, and the removable top which was a section of cheese cloth held in place by a rubber band or string. Strips of cheese cloth were used to make the seal between the screen and the frame.

The cages used to cover individual wheat plants (Plate II, Fig. 2) were 6 inch sections which had been cut from 42mm. glass tubing. The tube was held in place over the plant by a wire loop, and covered by a section of cheese cloth held in place by a rubber band.

<u>Miscellaneous Equipment</u>. The plants in the greenhouse were placed in a glass transfer chamber while insects were being removed from them. This chamber was large enough to accomodate a caged 6 inch pot, leaving enough room to perform the operation of collecting the insects with an aspirator. When an insect escaped from its cage during the transfer, the chamber prevented its further escape into the greenhouse, and made its recovery relatively easy.

A twenty cubic-centimeter pipette was used as an aspirator to make the transfers of individual leafhoppers. A rubber tube was attached to the mouth piece of the pipette, with a piece of screen covering the opening between the pipette and rubber

EXPLANATION OF PLATE II

Fig. 1. Cage used to cover several wheat plants in a six inch pot.

Fig. 2. Cages used to cover individual wheat plants in a six inch pot.

PLATE I

PLATE II

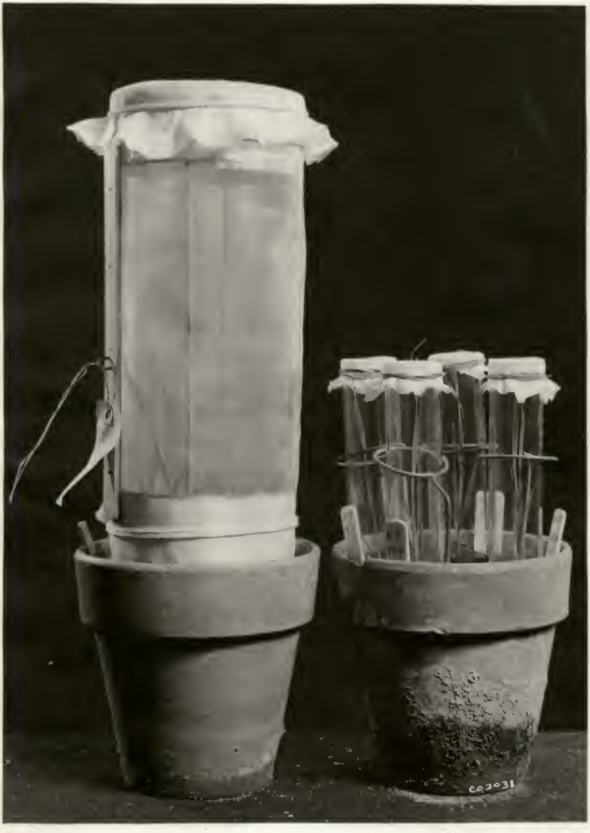

Fig. 1

Fig. 2

tubing. By inhaling a breath of air through the rubber tube, the leafhoppers were drawn into the bulb of the pipette; and by exhaling the breath they were expelled from the pipette. This type of an aspirator was described by Severin (1930).

A cylinder of carbon dioxide gas fitted with pressure valves and rubber tubing was used to anesthetize the insects while they were being identified. A flow of gas was directed into a dish containing the insects under magnification.

Methods

Collecting, Rearing and Identifying Insects. Most of the insects used in this work were collected by sweeping wheat with an insect net. The exceptions were some of the insects which appeared on wheat rather sporadically and were more easily collected on other plants. For example, *Aphis maidis* Fitch was more common on corn, *Hysteroneura setariae* (Thos.) was more common on "love grass", *Aphis gossippi* Glov. was more common on melon vines, and *Macrosiphum pisi* (Kalt.) was more easily collected on alfalfa. Most of the leafhoppers of the species *Endria inimica* (Say) that were collected in Riley County during the spring of 1951 were taken on brome grass, and a few other leafhoppers and Fulgorid species were collected on grasses bordering on wheat fields.

Three species of aphids - *Macrosiphum granarium* (Kirby), *Rhopalosiphum prunifoliae* (Fitch), and *Toxoptera graminum* (Rond.) - and two species of leafhoppers, - *Macrosteles divisus* (Uhler) and *Psammotettix* sp. - were maintained in colonies in the greenhouse through the winter. At least two other species of leafhoppers, *Exitianus exitiosus* (Uhler) and *Endria inimica* (Say) will reproduce on wheat and possibly could be maintained in colonies.

Insects which were recovered after they were used in the experiments were usually sent to specialists in the various groups for identification. Later in the course of these experiments, it was found to be possible to anesthetize the insects with carbon dioxide and identify some of them before they were used in the experiments. However, until more accessible characters than the internal male genitalia are known for some of the leafhoppers, it will continue to be impossible to make specific identifications previous to experimentation. This is particularly true, among the leafhoppers collected on wheat, of the Agalliini, and of the genera _Mesosteles_, _Psammotettix_, _Empoasca_, and _Deltocephalus_.

Transmission Experiments.

(1) Large numbers of insects on a row of infected and a row of healthy wheat plants in field cages.

The type of cage used in these experiments may be seen in Plate I. Two rows of wheat, each row about two feet long, were planted under each cage with a space of one foot between the rows. One of the two rows was inoculated when the plants were about three weeks old. A few days after the plants were inoculated each cage and its contents was thoroughly wetted with a 1 to 500 solution of nicotine sulfate and covered for several hours. Approximately ten days after one of the rows had been inoculated, the insects were placed in the cage. The insects to be used in each experiment were caged on infected plants in the greenhouse for at least one day before being used in the cages in the field. The pot of infected plants containing the insects was placed between an infected and healthy row of wheat in the field cage. This reduced the possibility that some of the insects might go directly to the uninoculated row and not be exposed to the virus.

The insects used were collected in Riley County. About 50 to 100 aphids were originally introduced into each field cage on the infected plants. In the case of the Cicadellids, approximately 250 individuals including several species were placed in each cage.

Toxoptera graminum (Rond.) and other aphids managed to gain entrance to most of the cages, and in some of the cages it was necessary to fumigate to prevent T. graminum from killing the plants.

In the late fall when the insects had been inactivated by freezing temperature, leaf samples were taken from both the test row and the inoculated row of each cage. Each of the leaf samples taken were used to inoculate healthy test plants. In addition, plants from each test row were brought to the greenhouse to be observed for the appearance of mosaic symptoms.

(2) Groups of insects caged on several infected wheat plants and subsequently transferred to several healthy wheat plants.

As soon as the insects were collected from the field they were separated into groups and caged on infected plants as illustrated in Plate II, Fig. 1. In a few of the experiments performed during the spring of 1951, the insects were anesthetized and identified when possible to species under magnification before they were caged on the infected plants. The insects were allowed to feed on the infected plants over a period of from 1 to 60 days. They were then immediately caged on healthy plants. The insects remained on the healthy plants either until they died, or were removed, but ordinarily no insects were removed until after they had been on the healthy plants for at least 10 days.

During the spring of 1951 an attempt was made to recover and preserve the insects remaining in the cage at the time of removal. In this way a second check could be made upon the identification of the species of insect involved in the experiment. After the insects were removed, the plants were periodically observed for symptoms of mosaic. Inoculum was prepared from the leaf tissue of plants which appeared to have mosaic symptoms. This material was then used to inoculate healthy test plants. If the test plant developed symptoms, it was then concluded that the symptoms were caused by the mosaic virus.

(3) Groups of insects collected in Riley County and caged on infected and healthy plants simultaneously.

Three different types of experiments were performed that came under this general heading. These three types were designated by the letters A, B, and C.

The type A experiments were made under the kind of cages illustrated in Plate II, Fig. 1. Each six inch pot contained about eight wheat seedlings and was divided into two equal parts, each half containing four plants. The plants in one half of the pot were infected with the mosaic virus, while the plants in the opposite half of the pot were allowed to remain healthy. As soon as the insects were collected from the field, they were divided into groups and caged on those pots containing both infected and healthy plants. The insects were left on these plants over a period of from 4 to 70 days, but usually until the insects died. After the insects were removed, the plants on the healthy side of the pot were observed for symptoms of mosaic.

The type B experiments were made under a large field cage of the type pictured in Plate I. The cage was situated on a bench in the greenhouse. Six inch pots containing only healthy wheat plants were placed under the cage beside other six inch pots containing only infected wheat plants. After the insects to be used in the experiment had been separated into groups, they were then caged on infected plants for at least one day before they were placed in the large cage with both the infected and the healthy plants. This made it more certain that the insects would feed on infected plants before they would feed on the healthy plants. The insects were left on the plants from 5 to 45 days. After the insects were removed, the healthy plants were observed for symptoms of mosaic. Inoculum was prepared from the leaf tissue of plants which appeared to have mosaic symptoms, and was used to inoculate healthy plants. If the healthy plants inoculated developed symptoms, it was concluded that the symptoms were caused by the mosaic virus.

No cages were used for the type C experiment. In these experiments, about 20 army cutworm larvae, <u>Chorizagrotis auxiliaris</u> (Grote), of various instars were used. The larvae were starved a few days before each experiment was attempted. The procedure then was to place the larvae on the infected wheat plants. When a larva was observed to have eaten a small area from an infected leaf it was immediately transferred to a healthy wheat plant. Each healthy plant had a larva transferred to it from an infected plant at least three times. The same larvae were used in all of the type C experiments.

(4) Insects collected on mosaic infected wheat fields in Western Kansas and caged directly on healthy wheat plants.

The insects were collected principally from wheat fields previously reported by Fellows and McKinney to be nearly 100 per cent infected with mosaic. The insects were collected in a net by sweeping the mosaic infected wheat. The insects, removed from the net with an aspirator, were anesthetized with carbon dioxide obtained from a bottle containing dry ice, and identified under a binocular microscope. As the insects were sorted into known groups, they were caged on healthy wheat plants, as illustrated in Plate II, Fig. 1.

The back seat of a 1946 model Ford sedan was converted into a small field laboratory by removing the seats and replacing them with a table, caged wheat plants, binocular microscope, anesthetizing bottle, and other equipment as may be seen in Plate III. It was possible to carry 18 caged six inch pots of wheat in the back seat without overcrowding.

(5) Individual insects caged on individual wheat plants.

The insects, principally leafhoppers collected in the field or reared, were caged on infected wheat plants for several days before they were transferred individually to single wheat plants, as illustrated in Plate II, Fig. 2. After a period of about two weeks on the healthy plants, the insects were removed, killed, mounted on points and identified. When an insect died in the cage it was removed as soon as possible to prevent it from being destroyed by mold.

PLATE III

RESULTS

Insects Collected on Wheat

Since a list of the insects which feed on wheat in Kansas would essentially be a list of the possible vectors of wheat mosaic, an attempt was made to prepare such a list. Collections were made on wheat in Riley County during the summer and fall of 1950 and the spring of 1951, and five collections were made in several of the Western Kansas counties during the same period.

No species of aphids were collected that had not previously been collected on wheat in Kansas. Leafhoppers belonging to 17 different genera were collected. Some indication of the relative abundance of the more common species is given in Table I. This table suggests that Mesosteles sp. and possible Psammotettix sp. are more common in Western Kansas than they are in Eastern Kansas. Since these collections varied in the number of sweeps per collection and as to the exact location it is probably valid to consider only large differences as indicative of relative abundance. For example, from Table 2 it should be safe to conclude that Exitianus exitiosus (Uhler) was more common in Western Kansas in August than was Endria inimica (Say), but that the reverse was true in June.

Osborn (1912) listed seven species of leafhoppers that he had observed making serious attacks on wheat. These were

Endria inimica (Say), Macrosteles divisus (Uhler), Exitianus exitiosus (Uhler), Paraphlepsius irroratus (Say), Deltocephalus balli Van D., Draeculacephala mollipes (Say), and Draeculacephala reticulata (Sign.). Although Osborn's statement was for North America as a whole, it agreed for the most part with the collections made in Kansas. The more common species of leafhoppers collected in Kansas are listed in Table 1.

In addition to the aphids and leafhoppers, members of 10 insect orders and 2 families of mites have been collected on wheat.

The following is a partial list of insects and mites collected in the field or greenhouse on wheat in Kansas, including especially those insects which have been, or should be used in transmission experiments with wheat mosaic:

*Collembola

Poduridae
- Achorutes armatus (Nic)
- Achorutes sp.

Isotomidae
- Isotoma viridis Bourlet
- Folsomia sp.

Sminthuridae
- Sminthurinus aureus (Lubb.)

Orthoptera

*Acrididae (several species)

Corrodentia

Pterodelidae
Lachesilla *nubilis* (Aaron)

Thysanoptera

*Thripidae
Prosopothrips *cognatus* Hood
Frankliniella *fusca* (Hinds)
Anaphothrips sp.

Aeolothripidae
Aeolothrips *bicolor* Hinds
Aeolothrips *fasciatus* L.

Hemiptera

Miridae
**Halticus* *bracteatus* (Say)
Leucopoecila *albofasciata* Reuter
**Trigonotylus* *ruficornis* (Geoffroy)
Ceratocapsus *fuscosignatus* Knight
Parthenicus sp.
**Lygus* *oblineatus* (Say)

Piesmidae
Piesma *cinera* (Say)

Coreidae
**Aufeius* *impressicollis* Stal

Lygaeidae
Nysius *raphanus* Howard
**Blissus* *leucopterus* (Say)

*Pentatomidae

Homoptera

*Delphacidae
**Delphacodes* *propinqua* (Fieb.)
Delphacodes *campestris* (Van D.)
Delphacodes *furcifer* (Herv.)
Delphacodes *consimilus* (Van D.)
Perigrinus *maidis* (Ash.)
Liburniella *ornata* (Stal)
Stobaera *tricarnata* (Say)
Kelesia *salina* Ball

Table 1. Relative abundance of the more common species of Cicadellidae collected on wheat at different periods of time during the fall of 1950 and the spring of 1951 in Eastern and Western Kansas[1]

Name of Cicadellid[2]	Aug. west[3]	Oct. west[3]	Nov. west[3]	May west[3]	June west[3]	Sep. east[3]	Oct. east[3]	June east[3]	Total
Macrosteles divisus (Uhler)	53	292	6	23	8	43	55	8	488
Exitianus exitiosus (Uhler)	172	31	26	0	1	8	9	11	258
Endria inimica (Say)	8	42	0	1	134	23	36	2	246
Nesosteles sp.	79	14	0	2	33	0	1	0	128
Psammotettix sp.	5	26	20	19	42	0	1	6	119
Deltocephalus sp.	13	17	5	0	1	3	12	0	51
Agalliini	5	60	13	0	5	0	7	0	90
Totals	334	482	70	45	224	77	121	27	1380

1 Only large differences should be considered as indicative of relative abundance.

2 The _Psammotettix_ sp. probably were mostly _P. striatus_ (L.). The _Nesosteles_ sp. probably were mostly _N. neglectus_ (Del & D). The _Deltocephalus_ sp. were probably mostly _D. sonorus_ Ball and _D. flavicosta_ (Stal). The Agalliini were probably _Aceratagallia_ sp. mostly _A. uhleri_ (Van D.) and _A. longula_ (Van D.).

3 West Kansas includes the following counties: Norton, Scott, Lane, Finney, Wallace, Ness, Greeley, Hodgeman, Reno, Edwards, Rush, Decatur, Kearny, and Hamilton. East Kansas includes only Riley and Pottawatomie counties.

Transmission Experiments

Large Numbers of Insects on a Row of Infected and a Row of Healthy Wheat Plants in Field Cages. These experiments are listed in Table 2. There was a total of 11 separate experiments or cages started on three different dates. The leaf samples taken from the healthy row of plants in each cage demonstrated that only the healthy row of wheat in cage 2a had been infected with the virus. The plants from this row that were brought into the greenhouse to grow did not develop mosaic symptoms, nor did symptoms appear on any of the plants taken from the healthy rows in the other cages.

The insect originally introduced into cage 2a was the Crown or Subterranean aphid, *Rhopalosiphum subterraneum* Mason. Other aphids including *Toxoptera graminum* (Rond.) entered into the experiment through contamination, but no leafhoppers were seen in the cage at any time. Attempts to establish colonies of *R. subterraneum* on wheat have not been successful in the greenhouse; consequently, this aphid has not been adequately tested. The only other experiment involving *R. subterraneum* is shown in Table 5. In this experiment the aphids were caged on healthy plants direct from the field without having fed on plants that were definitely known to have mosaic. The results of this experiment were negative.

Table 2. Transmission experiments involving large numbers of insects on a row of infected and a row of healthy wheat plants in field cages.

Cage No.	Name of insect[1]	Wheat planted	Wheat inoculated	Caged on infected plants	Insects introduced	Virus transferred from infected row to healthy row[2]
1a	*Toxoptera graminum* (Rond.)	Aug. 22	Sep. 7	Sep. 7	Sep. 19	negative
2a	*Rhopalosiphum subterraneum* Mason	Aug. 22	Sep. 7	Sep. 13	Sep. 19	positive
3a	*Aphis maidis* Fitch	Aug. 22	Sep. 7	Sep. 16	Sep. 19	negative
4a	Cicadellidae	Aug. 22	Sep. 7	Sep. 16	Sep. 19	negative
1b	*Toxoptera graminum* (Rond.)	Sep. 15	Oct. 6	Oct. 6	Oct. 15	negative
2b	*Rhopalosiphum prunifoliae* (Fitch)	Sep. 15	Oct. 6	Oct. 1	Oct. 15	negative
3b	*Aphis maidis* Fitch	Sep. 15	Oct. 6	Oct. 13	Oct. 15	negative
4b	Cicadellidae	Sep. 15	Oct. 6	Oct. 6	Oct. 15	negative
1c	*Toxoptera graminum* (Rond.)	Oct. 15	Nov. 5	Nov. 11	Nov. 15	negative
2c	*Rhopalosiphum prunifoliae* (Fitch)	Oct. 15	Nov. 5	Nov. 11	Nov. 15	negative
3c	check cage	Oct. 15	Nov. 5			negative
4c	Cicadellidae	Oct. 15	Nov. 5	Nov. 14	Nov. 15	negative

[1]The Cicadellidae included several species. Contamination with aphids was common.

[2]Leaf samples were collected on Dec. 1 from the healthy rows and inoculated to healthy plants.

Groups of Insects Caged on Several Infected Wheat Plants and Subsequently Transferred to Several Healthy Wheat Plants. These experiments are listed with the facts concerning them in Table 3. There was a total of 97 separate experiments; these are summarized in Table 6 along with the experiments listed in Tables 2, 4, and 5. At least one of the healthy test plants became infected in 5 of these experiments. There were 30 experiments involving unknown species of leafhoppers, and four of these resulted in a transfer of the virus. The experiments in which a transfer of the virus occurred may be referred to in Table 7 under the identification marks C, F, R, and L3-10.

The other positive experiment was one involving the wheat stem maggot adult, Meromyza americana Fitch. This experiment is listed in Table 7 under the identification mark L15-4. Four other experiments involving M. americana which are listed in Table 3 were negative.

The details concerning the positive experiments designated by the identification marks C, F, R, L3-10 and L15-4, in addition to being given in Table 7, are described below.

The leafhoppers used in experiment C were collected at the mosaic nursery at Manhattan, Kansas, and caged on infected plants on October 4, 1950. On October 6, 1950, about 20 of these leafhoppers were transferred to healthy plants in pot C. On October 25, 1950, all of the leafhoppers were removed. The leafhoppers were on the infected plants two days and on the healthy plants for 19 days. Symptoms were first observed on a plant in pot C on November 23, 1950. Inoculum was prepared from the plant in pot C bearing mosaic symptoms, and was inoculated to healthy plants in four pots. After a period of three to four months the plants in two of the four pots developed mosaic symptoms while the other two remained healthy. This may have been caused by a concentration of virus in the inoculum, approaching the dilution end point. A duplicate group of 29 leafhoppers collected at the same time and in the same place as the leafhoppers used in experiment C was preserved and identified. These leafhopper species are listed in Table 8. Apparently Macrosteles divisus (Uhler) and Endria inimica (Say) were the species most likely involved in the transmission.

The leafhoppers used in experiment F were collected on the mosaic nursery at Manhattan, Kansas, and caged on infected plants on September 27, 1950. On October 2, 1950, about 10 of these leafhoppers were transferred to healthy plants in pot F. On October 25, 1950, all of the leafhoppers were removed. The leafhoppers were on the infected plants 5 days and on the healthy plants for 23 days. Symptoms were first observed on a plant in pot F on March 3, 1951. The inoculum prepared from the plant in pot F bearing mosaic symptoms caused symptoms to appear on healthy plants to which it was inoculated after 14 days. A duplicate group of 54 leafhoppers collected at the same time and in the same place as the leafhoppers used in experiment F was preserved and identified. The only leafhoppers in this duplicate collection were Macrosteles divisus (Uhler), Endria inimica (Say), and Exitianus exitiosus (Uhler). These leafhoppers are listed in Table 8.

The leafhoppers used in experiment R were collected at Casement Ranch at Manhattan, Kansas and caged on infected plants on October 20, 1950. On October 26, 1950 four of these leafhoppers that were superficially similar in appearance to Endria inimica (Say) were transferred to healthy plants in pot R. On November 15, 1950 when the cage was removed all of the leafhoppers were dead of missing. The leafhoppers were on the infected plants for 6 days and on the healthy plants not longer than 20 days. Symptoms were first observed on a plant in pot R on December 7, 1950. Inoculum was prepared from the plant in pot R bearing mosaic symptoms and inoculated to healthy plants in four pots. After a period of less than one month all of the plants in the four pots had developed mosaic symptoms. A duplicate group of 19 leafhoppers collected at the same time and in the same place as the leafhoppers caged on the infected plants used in experiment R was preserved and identified. The most common leafhopper in this duplicate collection was Endria inimica (Say) according to the data in Table 8.

The applie grain aphid, Rhopalosiphum prunifoliae (Fitch) had infested the plants on pot R through contamination. The plant was fumigated with nicotine on November 15, 1950 when the cage was removed.

The leafhoppers used in exper[illegible]t L3-10 were coll[illegible]cted at Manhattan, Kansas and caged on infected plants on November 18, 1950. On November 24, 1950 six of these leafhoppers were transferred to healthy plants in pot L3-10. By December 14, 1950 all of the adult leafhoppers were dead, but their progeny was present on the plant as nymphs. On January 5, 1951 all of the nymph leafhoppers were removed. The leafhoppers were on the infected plant 6 days and on the healthy plant not longer than 20 days. Symptoms were first observed on a plant in pot L3-10 on April 25, 1951. Inoculum was prepared from the plant in pot L3-10 bearing mosaic symptoms and inoculated to several healthy test plants. Mosaic symptoms developed on the test plants after a period of less than two weeks. No duplicate collections were preserved for this experiment, but Macrosteles divisus (Uhler) was probably the chief leafhopper involved.

The apple grain aphid, Rhopalosiphum prunifoliae (Fitch) was present on the plants in pot L3-10. The plant was fumigated on January 5, 1951 when the cage was removed.

The Meromyza americana Fitch adults used in experiment L15-4 were collected from volunteer wheat being used in connection with other experiments in the greenhouse on February 14, 1951. After being caged on an infected plant for 3 days about 12 adults were transferred to the healthy plants in pot L15-4. All of the flies were dead by March 21, 1951. Symptoms were first observed on a plant in pot L15-4 on April 25, 1951. Inoculum was prepared from the plant in pot L15-4 bearing the mosaic symptoms and inoculated to several healthy test plants. Mosaic symptoms developed on the test plants after a period of less than two weeks. The _M. americana_ adults were on the infected plants for 4 days and on the healthy plants not longer than 32 days.

Groups of Insects Collected in Riley County and Caged on Infected and Healthy Plants Simultaneously. The data from these experiments are listed in Table 4. There was a total of 30 separate experiments; these are summarized in Table 6 along with the experiments listed in Tables 2,3, and 5. There were 6 experiments involving unknown species of leafhoppers, and three of these resulted in a transfer of the virus. The experiments in which a transfer of the virus occurred may be referred to in Table 7 under the identification marks M, L1-7, and L1-8, and the details pertaining to each experiment are described below.

Experiment M was a "type B" experiment which is described on pages 15 and 16. The leafhoppers used in experiment M were collected on several dates during October at Manhattan, Kansas. As the leafhoppers were collected they were placed in a large cage containing several pots of infected plants and pots M and N were removed from the cage. Symptoms of mosaic were first noted on a plant in pot M on November 25, 1950.

Table 3. Transmission experiments involving groups of insects caged on several infected wheat plants and subsequently transferred to several healthy wheat plants.

Pot Mark	Name of insects[1]	Caged on plants: Infected	healthy	Insects removed[2]	No. of insects[3]	County where collected
A	Aphis maidis Fitch	Sep. 27	Oct. 7	Oct. 25	5	Riley
A	Toxoptera graminum (Rond)	Sep. 27	Oct. 7	Oct. 25	5	Riley
A	Macrosiphum granarium (Kirby)	Sep. 27	Oct. 7	Oct. 25	5	Riley
B	Cicadellidae	Oct. 4	Oct. 10	Oct. 25	20	Riley
C	Cicadellidae[4]	Oct. 4	Oct. 6	Oct. 25	20	Riley
D	Hysteroneura setariae (Thos)	Aug. 30	Sep. 2	Sep. 5	10	Riley
		Sep. 6	Sep. 7	Sep. 10	10	Riley
E	Aphis gossypii Glov.	Aug. 30	Sep. 2	Sep. 5	20	Riley
		Sep. 6	Sep. 7	Sep. 10	20	Riley
F	Cicadellidae[4]	Sep. 27	Oct. 2	Oct. 25	10	Riley
G	Cicadellidae	Sep. 22	Sep. 26	Oct. 25	10	Riley
H	Halticus bracteatus (Say)	Sep. 20	Sep. 26	Oct. 25	25	Riley
H	Trigonotylus ruficornis (Goffery)	Sep. 20	Sep. 26	Oct. 25	10	Riley
J	Cicadellidae	Oct. 16	Oct. 21	Nov. 14	25	Decatur, Norton
K	Cicadellidae	Oct. 16	Oct. 21	Nov. 14	25	Hamilton

Table 3. (Cont.)

Pot Mark	Name of insects[1]	Caged on plants: Infected	healthy	Insects removed[2]	No. of insects[3]	County where collected
L	Cicadellidae	Oct. 16	Oct. 21	Nov. 14	25	Wallace, Greeley
O	Cicadellidae	Oct. 20	Oct. 26	Nov. 15	10	Riley
P	Cicadellidae	Oct. 11	Oct. 25	Nov. 15	10	Riley
Q	Cicadellidae	Oct. 12	Oct. 26	Nov. 15	10	Riley
R	Cicadellidae[4]	Oct. 20	Oct. 26	Nov. 15	4	Riley
S	<u>Halticus bracteatus</u> (Say)	Oct. 20	Oct. 26	Nov. 29	50	Riley
T	Cicadellidae	Oct. 4	Oct. 26	Nov. 15	10	Riley
U	<u>Trigonotylus ruficornis</u> (Goffery)	Sep. 20	Sep. 26	Nov. 15	10	Riley
U	<u>Halticus bracteatus</u> (Say)	Sep. 20	Sep. 26	Nov. 15	5	Riley
V	Cicadellidae	Oct. 27	Nov. 7	Nov. 29	10	Riley
W	Cicadellidae	Oct. 20	Oct. 26	Nov. 29	3	Riley
X	Cicadellidae	Oct. 11	Oct. 15	Nov. 29	10	Riley
Y	<u>Toxoptera graminum</u> (Rond.)	Oct. 20	Oct. 17	Dec. 7	5	Riley

Table 3. (Cont.)

Pot Mark	Name of insects[1]	Caged on plants infected	Caged on plants healthy	Insects removed[2]	No. of insects[3]	County where collected
Z	Macrosiphum pisi (Kalt.)	Oct. 18	Oct. 20	Dec. 7	20	Riley
A-1	Cicadellidae	Nov. 15	Nov. 20	Feb. 4	10	Riley
B-1	Cicadellidae	Nov. 15	Nov. 16	Dec. 14	10	Riley
L1-9	Cicadellidae	Nov. 15	Nov. 17	Dec. 14	10	Riley
L2-9	Halticus bracteatus (Say)	Nov. 15	Nov. 17	Dec. 7	10	Riley
L2-10	Lygus oblineatus (Say)	Nov. 15	Nov. 17	Dec. 14	3	Riley
L2-11	Toxoptera graminum (Rond.)	Oct. 20	Nov. 21	Dec. 7	5	Riley
L2-12	Aphis gossypii Glov.	Nov. 20	Nov. 21	Dec. 7	50	Riley
L2-13	Cicadellidae	Nov. 15	Nov. 21	Feb. 4	10	Riley
L3-1	Chorizagrotis axilaris (Grote)	Nov. 24	Dec. 16	Jan. 18	10	Riley
L3-7	Cicadellidae	Nov. 15	Nov. 22	Feb. 4	8	Riley
L3-8	Exitianus exitiosus (Uhler)	Nov. 16	Nov. 22	Dec. 14	8	Riley
L3-9	Cicadellidae	Nov. 22	Nov. 24	Dec. 14	12	Riley
L3-10	Cicadellidae[4]	Nov. 17	Nov. 24	Jan. 5	9	Riley

Table 3. (Cont.)

Pot Mark	Name of insects[1]	Caged on plants: Infected	healthy	Insects removed[2]	No. of insects[3]	County where collected
L4-1	Cicadellidae	Nov. 21	Nov. 24	Nov. 28	14	Gray, Haskell, Stevens
L4-2	Cicadellidae	Nov. 21	Nov. 24	Nov. 28	16	Scott
L4-3	Psammotettix sp.	Nov. 21	Nov. 24	Nov. 28	2	Gray, Haskell, Stevens
L4-4	Cicadellidae	Nov. 20	Nov. 24	Nov. 28	14	Gray, Haskell, Stevens
L4-5	Halticus bracteatus (Say)	Nov. 21	Nov. 24	Dec. 20	1	Gray, Haskell, Stevens
L4-6	Chorizagrotis axilaris (Grote)	Nov. 28	Nov. 29	Dec. 20	1	Riley
L4-7	Macrosiphum granarium (Kirby)	Nov. 30	Dec. 7	Jan. 5	3	Marshall
L6-20	Toxoptera graminum (Rond.)	Dec. 7	Dec. 21	Jan. 13	3	Riley
L8-17	Thripidae	Dec. 11	Jan. 11	Feb. 4	50	Riley
L9-8	Macrosiphum granarium (Kirby)	Nov. 16	Dec. 26	Jan. 23	5	Riley
L10-1	Cicadellidae	Jan. 5	Jan. 12	Feb. 28	13	Riley

Table 3. (Cont.)

Pot Mark	Name of insects[1]	Caged on plants infected	Caged on plants healthy	Insects removed[2]	No. of insects[3]	County where collected
L10-2	Cicadellidae	Nov. 15	Jan. 5	Feb. 28	10	Riley
L10-3	Cicadellidae	Jan. 12	Jan. 13	Mar. 15	12	Riley
L10-4	Cicadellidae	Jan. 5	Jan. 27	Mar. 15	12	Riley
L13-5	_Macrosteles divisus_ (Uhler)	Jan. 10	Feb. 13	Mar. 15	11	Riley
L14-1	Thripidae	Jan. 4	Feb. 4	Feb. 28	50	Riley
L14-9	_Chorizagrotis axilaris_ (Grote)	Nov. 21	Jan. 18	Apr. 28	8	Finney, Scott
L14-10	_Macrosteles divisus_ (Uhler)	Jan. 5	Jan. 31	Feb. 9	50	Riley
L15-1	_Macrosteles divisus_ (Uhler)	Jan. 5	Feb. 13	Apr. 7	12	Riley
L15-2	_Macrosteles divisus_ (Uhler)	Jan. 5	Feb. 6	Feb. 15	10	Riley
L1f-4	_Mermoyza americana_[4] Fitch	Feb. 14	Feb. 17	Mar. 21	12	Riley
L15-5	_Trialeurodes vaporariorum_ (Westwood)	Feb. 20	Feb. 22	Feb. 28	50	Riley

Table 3. (Cont.)

Pot Mark	Name of insects[1]	Caged on plants infected	healthy	Insects removed[2]	No. of insects[3]	County where collected
L18-1	*Aphis maidis* Fitch	Feb. 26	Mar. 3	Mar. 28	300	Riley
L18-2	*Aphis maidis* Fitch	Feb. 24	Feb. 26	Mar. 28	50	Riley
L18-3	*Aphis maidis* Fitch	Feb. 24	Feb. 26	Apr. 7	50	Riley
L18-4	*Macrosteles divisus* (Uhler)	Jan. 5	Feb. 26	Mar. 28	10	Riley
L21-10	*Endria inimica* (Say)	May 26	June 1	Apr. 14	30	Riley
L25-9	Delphacidae	Apr. 23	Apr. 17	May 8	10	Riley
L25-10	Delphacidae	Apr. 13	Apr. 17	May 8	12	Riley
L26-6	*Endria inimica* (Say)	May 26	June 1	Apr. 14	25	Riley
L28-1	Cicadellidae	Apr. 27	Apr. 30	May 18	20	Riley
L28-2	*Macrosteles divisus* (Uhler)	May 2	May 3	May 10	7	Riley
L28-3	*Nesosteles* sp.	May 2	May 3	May 8	2	Riley
L28-4	*Pachynematus* sp. (sawfly larvae)	May 2	May 3	May 8	12	Riley
L30-1	*Meromyza americana* Fitch	May 11	May 14	May 25	20	Riley

Table 3. (Cont.)

Pot Mark	Name of insects[1]	Caged on plants infected	healthy	Insects removed[2]	No. of insects[3]	County where collected
L30-2	*Meromyza americana* Fitch	May 11	May 14	May 25	16	Riley
L30-3	*Nesosteles* sp.	May 11	May 14	May 25	30	Riley
L30-4	*Nesosteles* sp.	May 11	May 14	May 25	30	Riley
L30-5	*Endria inimica* (Say)	May 11	May 14	June 8	26	Riley
L30-6	*Endria inimica* (Say)	May 17	May 25	June 8	10	Riley
L30-7	*Endria inimica* (Say)	May 17	May 25	June 8	10	Riley
L31-7	*Nesosteles* sp.	May 15	May 18	June 8	10	Riley
L31-8	*Endria inimica* (Say) nymphs	May 17	May 18	June 8	10	Riley
L31-9	*Trigonotylus ruficornis* (Goffery)	May 15	May 18	May 25	15	Riley
L32-2	*Endria inimica* (Say) nymphs	May 20	May 23	July 2	10	Riley
L32-3	*Endria inimica* (Say) nymphs	May 20	May 25	July 2	10	Riley
L32-4	*Endria inimica* (Say)	May 20	May 28	July 2	18	Riley
L32-5	*Endria inimica* (Say nymphs	May 17	May 23	July 2	12	Riley

Table 3. (Cont.)

Pot Mark	Name of insects[1]	Caged on plants infected	Caged on plants healthy	Insects removed[2]	No. of insects[3]	County where collected
L32-9	*Endria inimica* (Say) nymphs	May 23	May 26	June 8	25	Riley
L33-1	*Meromyza americana* Fitch	May 25	May 28	June 8	15	Riley
L33-2	*Meromyza americana* Fitch	May 25	May 28	June 8	15	Riley
L33-3	*Endria inimica* (Say)	May 23	May 28	June 8	25	Riley
L33-5	*Endria inimica* (Say)	May 23	May 29	June 8	20	Riley
L33-6	*Endria inimica* (Say)	May 26	May 30	June 8	30	Riley
L33-9	*Endria inimica* (Say)	May 29	May 31	July 2	15	Riley
L33-10	*Endria inimica* (Say)	May 29	June 9	July 2	10	Riley
L34-1	*Endria inimica* (Say)	May 23	May 31	June 14	10	Riley
L34-2	*Endria inimica* (Say)	May 26	June 8	June 14	10	Riley
L34-3	*Endria inimica* (Say)	May 26	June 6	June 14	10	Riley

Table 3. (Concl.)

Pot Mark	Name of insects[1]	Caged on plants infected	healthy	Insects removed[2]	No. of insects[3]	County where collected
L34-5	*Endria inimica* (Say)	May 29	June 5	June 14	14	Riley

[1] The insects listed as Cicadellidae were usually groups of several species. *Psammotettix* sp. probably were mostly *P. striatus* (L.). The *Nesosteles* sp. probably were mostly *Nesosteles neglectus* (Del & D.).

[2] In some cases the insects had died at a time previous to the date of removal. It is not valid to calculate the number of days a group of insects were on the healthy plants from the date the insects were placed on the healthy plant and the date of removal.

[3] The figures indicating the number of insects used in each experiment were approximations.

[4] A transfer of the virus was obtained in these experiments.

On December 11, 1950 the virus was transferred to healthy plants in four pots. Symptoms of mosaic never appeared on the plants in pot N although they apparently had been subjected to the same conditions as were the plants in pot M.

Experiments L1-7 and L1-8 were "type B" experiments which are described on pages 15 and 16. The leafhoppers used in these experiments were collected at Manhattan, Kansas on November 15, 1950. The leafhoppers, after remaining on infected plants for a day, were placed in a large cage containing several pots of infected plants and pots L1-7 and L1-8 containing healthy plants. On December 20, 1950 pots L1-8 and L1-7 were removed from the cage. Symptoms of mosaic were first noted on both pots L1-7 and L1-8 on April 25, 1951, and the virus was transferred to healthy plants from plants in both pots.

On January 11, 1951 the healthy plants in pots L8-16 and L4-9 were placed in this same cage with the same infected plants and also all of the same leafhoppers, or their progeny, that were still alive. The virus was not transferred to the plants in these pots.

No duplicate collections were made for these experiments, but some of the same leafhoppers were later used in tests with individual leafhoppers. The great majority of these proved to be _Macrosteles divisus_ (Uhler) but _Exitianus exitiosus_ (Uhler), _Deltocephalus sonorus_ Ball, and some Delphacis were also represented.

Table 4. Transmission experiments involving groups of insects collected in Riley County and caged on infected and healthy wheat plants simultaneously.[1] See footnote number 4.

Pot Mark	Name of insects[2]	Date applied	Insects removed	No. of insects[3]	Type of experiment	Results
M	Cicadellidae	Oct. 1	Nov. 15	250	B	positive
N	Cicadellidae	Oct. 1	Nov. 15	250	B	negative
L1-7	Cicadellidae	Nov. 16	Dec. 20	150	B	positive
L1-8	Cicadellidae	Nov. 16	Dec. 20	150	B	positive
L4-9	Cicadellidae	Jan. 11	Jan. 23	150	B	negative
L8-16	Cicadellidae	Jan. 11	Jan. 23	150	B	negative
L13-2	*Chorizagrotis auxilaris* (Grote)	Feb. 28	Mar. 9	6	A	negative
L13-4	*Aphis maidis* Fitch	Feb. 22	Mar. 28	500	A	negative
L13-18	Acrididae nymphs	Feb. 13	Mar. 21	4	A	negative
L13-19	Acrididae nymph	Jan. 27	Apr. 7	1	A	negative
L16-2	*Macrosteles divisus* (Uhler)	Feb. 21	Mar. 21	100	B	negative
L17-1	*Macrosteles divisus* (Uhler)	Feb. 21	Mar. 21	100	B	negative
L17-2	*Chorizagrotis auxiliaris* (Grote)	Feb. 28	Feb. 28	20	C	negative

Table 4. (Cont.)

Pot Mark	Name of insects[2]	Date applied	Insects removed	No. of insects[3]	Type of experiment	Results
L17-3	*Chorizagrotis auxiliaris* (Grote)	Feb. 28	Feb. 28	20	C	negative
L17-4	*Chorizagrotis auxiliaris* (Grote)	Mar. 6	Mar. 6	20	C	negative
L17-5	*Chorizagrotis auxiliaris* (Grote)	Mar. 6	Mar. 6	20	C	negative
L18-9	*Toxoptera graminum* (Rond.)	Mar. 15	Mar. 28	5	A	negative
L18-10	*Rhopalosiphum prunifoliae* Fitch	Mar. 15	Mar. 28	5	A	negative
L19-3	*Chorizagrotix auxiliaris* (Grote)	Mar. 3	Mar. 3	20	C	negative
L19-5	*Macrosiphum granarium* (Kirby)	Apr. 7	Apr. 30	25	A	negative
L19-6	*Toxoptera graminum* (Rond.)	Apr. 23	May 17	5	A	negative
L19-8	Dalphaeidae	Apr. 13	Apr. 17	25	A	negative
L20-4	*Macrosteles divisus* (Uhler)	Mar. 21	Apr. 7	25	B	negative
L20-5	*Macrosteles divisus* (Uhler)	Mar. 21	Apr. 7	25	B	negative
L23-1	*Psammotettix* sp.	Apr. 9	Apr. 14	10	B	negative

Table 4. (Cont.)

Pot Mark	Name of insects[2]	Date applied	insects removed	No. of insects[3]	Type of experiment	Results
L24-1	*Psammotettix* sp.	Apr. 9	Apr. 14	10	B	negative
L31-5	*Endria inimica* (Say) nymphs	May 18	June 8	50	B	negative
L31-6	*Endria inimica* (Say) nymphs	May 18	June 8	50	B	negative
L32-8	*Endria inimica* (Say) nymphs	May 23	June 14	50	B	negative
L32-10	*Endria inimica* (Say) nymphs	May 23	June 14	50	B	negative

[1] In the case of the experiments of type B, the insects were caged on infected plants at least one day before they were introduced into the cages containing both infected and healthy plants.

[2] In most cases insects listed by the family name such as Cicadellidae or Acrididae were groups of several unidentified species. The Psammotettix sp. probably were mostly *Psammotettix striatus* (L.).

[3] The figures of 50 or more, indicating the number of insects used in each esperiment, are approximations.

[4] The type of experiment designated by the letter A was one in which a six inch pot containing about eight wheat seedlings was divided in half with the four plants in one half infected and the four plants in the other half healthy. Experiment B was of the type in which a pot containing only infected wheat plants was placed in a large cage with a pot containing only healthy wheat on either side of it. The type C experiment was performed only with the army cutworm, *Chorizagrotis ausiliaris* (Grote). This type deviated from B only in that the insects were transferred manually from infected to healthy plants and vice versa several times, and that the transferrengs continued over only about a two hour period.

Insects Collected on Mosaic Wheat Fields in Western Kansas and Caged Directly on Healthy Wheat Plants. The data pertaining to these experiments are listed in Table 5, and the method used in carrying them out is described on pages 16 and 17.

There was a total of 46 separate experiments, these are summarized in Table 6 along with the experiments that are listed in Tables 2, 3, and 4.

The insects were placed on the healthy test plants in the majority of these experiments on one of the following dates: June 4, 5, 6, 9, or 10, 1951. None of the plants in these experiments had developed symptoms of mosaic by July 7, 1951; but, it would not be safe to assume that none of them will develop mosaic symptoms, since probably more than a month has been required for symptoms to appear on plants that may have been inoculated by insects.

Plants listed in Table 5 by the pot marks L34-11, L34-12, L34-13, L34-14, L34-17, L34-18, L35-6, and L35-8 were subjected to a cold shock of 40° F. from June 15, 1951 to June 18, 1951. These plants were exposed to the following insects which had been collected on mosaic infected fields: Miscellaneous insects including Lygaeidae, Pentatomidae and others, Empoasca sp., Nesosteles sp. Endria inimica (Say), Meromyza americana Fitch, Delphacidae, Agalliini, and Endria inimica (Say). This cold shock treatment apparently has not enhanced the development of mosaic symptoms.

Table 5. Transmission experiments involving insects collected in mosaic infected wheat fields in Western Kansas and caged directly on healthy plants. All these experiments were negative up until July 7, 1951.

Pot mark[1]	Name of insects[2]	Date applied	Date insects removed	No. of insects[3]	County where collected[4]
I	Cicadellidae	Oct. 18	Nov. 14	25	Greeley
L1-10	Cicadellidae	Nov. 21	Nov. 24	50	Kearny
L1-11	Toxoptera graminum (Rond.)	Nov. 20	Nov. 24	15	Morton and Finney
L1-12	Rhopalosiphum subterraneum Mason	Nov. 20	Dec. 9	10	Morton, Finney Stevens
L23-5	Cicadellidae	Apr. 3	Apr. 9	35	Ness
L23-6	Cicadellidae	Apr. 3	Apr. 9	35	Lane
L23-7	Cicadellidae	Apr. 3	Apr. 9	35	Lane
L23-8	Cicadellidae and Delphacidae	Apr. 4	Apr. 9	30	Finney
L23-9	Cicadellidae[5]	Apr. 4	Apr. 9	50	Finney
L24-9	Cicadellidae and Delphacidae	Apr. 27	May 1	20	Finney, Wichita, Scott and Greeley
L25-8	Endria inimica (Say)	June 9	July 2	52	Same as L34-14 and L35-1, L35-2, L35-8

Table 5. (Cont.)

Pot Mark[1]	Name of insects[2]	Date applied	Date insects removed	No. of insects[3]	County where collected[4]
L34-4a	Deltocephalus sp.	June 10	July 2	4	Same as L34-15
L34-4b	Hecalini	June 10	June 18	2	Same as L34-15
L34-4c	Hecalini	June 10	July 2	2	Same as L34-15
L34-7a	Meromyza americana Fitch	June 10	July 2	1	Ness and Finney
L34-7b	Pentatomidae	June 10	July 2	2	Ness, Hodgeman, Finney
L34-7c	Lygaeidae	June 10	July 2	2	Ness, Hodgeman, Finney
L34-8	Nesosteles sp.	June 10	July 2	14	Same as L34-13
L34-9	Psammotettix sp.	June 10	July 2	16	Same as L35-3
L34-10	Macrosteles divisus	June 9	July 2	6	Same as L35-4
L34-11	Miscellaneous insects	June 4	June 10	23	Ness, Hodgeman, Finney
L34-12	Empoasda sp.	June 4	June 9	3	Ness and Finney
L34-13	Nesosteles sp.	June 4	June 10	33	Ness, Hodgeman, Finney
L34-14	Endria inimica (Say)	June 4	June 9	65	Ness, Hodgeman, Finney

Table 5. (Cont.)

Pot mark[1]	Name of insects[2]	Date applied	insects removed	No. of insects[3]	County where collected[4]
L34-15	Cicadellidae	June 4	June 10	25	Ness, Hodgeman, Finney
L34-16	<u>Trigonotylus</u> <u>ruficornis</u> (Goffery)	June 4	June 9	14	Ness, Hodgeman, Finney
L34-17	<u>Meromyza</u> <u>americana</u> Fitch	June 4	June 9	12	Ness, Hodgeman, Finney
L34-18	Delphacidae	June 4	June 10	37	Ness, Hodgeman, Finney
L34-19a	Acrididae nymphs	June 6	June 10	2	Finney
L34-19b	<u>Toxoptera</u> <u>graminum</u> (Rond.)	June 6	June 10	5	Finney
L34-19c	Thripidae	June 4	June 10	6	Finney
L34-20a	Thripidae	June 4	June 10	6	Ness and Hodgeman
L34-20b	Collembola	June 4	June 10	3	Ness and Hodgeman
L34-20c	<u>Prosothrips</u> <u>cognatus</u> Hood	June 4	June 10	32	Ness and Hodgeman
L35-1	<u>Endria</u> <u>inimica</u> (Say)	June 5	June 10	35	Hodgeman and Finney
L35-2	<u>Endria</u> <u>inimica</u> (Say)	June 4	June 9	12	Ness and Finney
L35-3	<u>Psammotettix</u> sp.	June 4	June 10	42	Ness, Hodgeman, Finney
L35-4	<u>Macrosteles</u> <u>divisus</u> (Uhler)	June 4	June 9	9	Ness, Hodgeman, Finney

Table 5. (Cont.)

Pot Mark[1]	Name of insects[2]	Date insects applied	Date insects removed	No. of insects[3]	County where collected[4]
L35-5	Aphididae	June 4	June 9	3	Ness
L35-6	Agalliini	June 4	June 9	5	Ness and Hodgeman
L35-7	Agromyza coquilletti Mall.	June 5	June 9	15	Hodgeman
L35-8	Endria inimica (Say)	June 6	June 9	20	Finney
L35-9	Delphacidae	June 10	July 2	14	Same as L34-18
L35-10a	Agalliini [5]	June 9	July 2	1	Ness and Hodgeman
L35-10b	Agalliini	June 9	July 2	1	Ness and Hodgeman
L35-10c	Agalliini	June 9	July 2	1	Ness and Hodgeman

[1] The letters a,b, and c following pot marks L34-4, -7,-19,-20, and L35-10 indicate single plants in a pot on which insects were caged. Plants bearing the pot marks L34-11,-12,-13,-14,-17,-18, and L35-6,-8, were subjected to a temperature of 40° F. from June 15, 1951 to June 18, 1951.

[2] In most cases insects listed by the family name such as Cicadellidae, Delphacidae or Aphididae were groups of several unidentified species. The *Psammotettix* sp. probably were mostly *Psammotettix striatus* (L.). The *Nesosteles* sp. probably were mostly *Nesosteles neglectus* (DeL & D). The Agalliini were probably *Aceratagallia* sp. mostly *A. uhleri* (Van D.) and *A. longula* (Van D.).

Table 5. (Concl.)

[3] Figures given indicating the number of insects used in each of the first ten experiments are approximations.

[4] In this column a reference to a pot mark, (L34-18) indicates that the insects in question were transferred from the plant or plants bearing that pot mark.

Table 6. A condensation of the transmission experiments in the field and greenhouse involving groups of insects that are listed in Tables 2, 3, 4, and 5.

Group	Species	No. of experiments	Approximate no. of insects
Cicadellidae	Several	48	2100
Cicadellidae	Endria inimica (Say)	29	700
Cicadellidae	Macrosteles divisus (Uhler)	12	350
Cicadellidae	Nesosteles sp.	6	120
Cicadellidae	Psammotettix sp.	5	80
Cicadellidae Agalliini	Several	4	8
Cicadellidae Heèalini	Undetermined	2	4
Cicadellidae	Exitianus exitiosus (Uhler)	1	6
Cicadellidae	Deltocephalus sp.	1	3
Cicadellidae	Empoasca sp.	1	3
Aphididae	Several	1	3
Aphididae	Toxoptera graminum (Rond.)	11	350
Aphididae	Aphis maidis Fitch	7	1100

Table 6. (Cont.)

Group	Species[1]	No. of experiments	Approximate no. of insects
Aphididae	*Rhopalosiphum prunifoliae* (Fitch)	3	350
Aphididae	*Macrosiphum granarium* (Kirby)	4	38
Aphididae	*Rhopalosiphum subterraneum* Mason	2	60
Aphididae	*Hysteroneura setariae* (Thos.)	1	20
Aphididae	*Aphis gossypii* Glov.	2	90
Aphididae	*Macrosiphum pisi* (Kalt)	1	20
Miridae	*Halticus bracteatus* (Say)	5	100
Miridae	*Trigonotylus ruficornis* (Goffrey)	4	49
Miridae	*Lygus pratensis* (Say)	1	3
Pentatomidae	Undetermined	1	2
Lygaeidae	Undetermined	1	2
Aleyrodidae	*Trialeurodes vaporariorum* (Westwood)	1	50
Delphacidae	Several	7	150
Thripidae	Several	4	100
Thripidae	*Prosothrips cognatus* Hood	1	32
Collembola	Undetermined	1	3

Table 6. (Concl.)

Group	Species[1]	No. of experiments	Approximate no. of insects
Agromyzidae	Agromyza coquilletti Mall.	1	15
Chloropidae	Meromyza americana Fitch	7	90
Acrididae	Several	3	7
Noctuidae	Chorizagrotis auxiliaris (Grote)	9	125
Tenthredinidae	Pachynematus spp.	1	12
Total		189	6178

[1] The Psammotettix sp. probably were mostly Psammotettix striatus (L.). The Nesosteles sp. probably were mostly Nesosteles neglectus (Del & D). The Agalliini were probably Aceratagallia spp. mostly Aceratagallia uhleri (Van D.) and Aceratagallia longula (Van D.). The Deltocephalus spp. were probably Deltocephalus sonorus Ball or Deltocephalus flaviocosta (Stal.). The Delphacidae were probably Delphacodes spp.

Table 7. A comparison of the transmission experiments in which a transfer of the virus occurred.

Identification mark	Insect group or species[1]	Maximum no. of days on plants: Infected	Maximum no. of days on plants: healthy	No. of insects used[2]	Age of plants when infected in days	Refer to table no.	Refer to text page
C	Cicadellidae	2	19	20	29	3	27
F	Cicadellidae	5	23	10	25	3	28
M	Cicadellidae	46	46	250	24	4	31
R	Cicadellidae	6	20	4	49	3	29
L1-7	Cicadellidae	34	34	150	38	4	40
L1-8	Cicadellidae	34	34	150	38	4	40
L3-10	Cicadellidae	6	20	9	26	3	30
L15-4	*Meromyza americana* Fitch	3	32	12	31	3	30
2a	*Rhopalosiphum subterraneum* Mason	78	78	50	28	2	25

[1] A part of each collection of Cicadellidae used in experiments C, F, M, and R, were preserved and later identified. These duplicate collections are listed in table 9. L1-7 and L1-8 probably included mostly *Macrosteles divisus* (Uhler) but possibly with some *Exitanus exitiosus* (Uhler) and *Deltocephalus sonorus* Ball also used in the experiments. L3-10 probably included *Macrosteles divisus* (Uhler) and *Exitianus exitiosus* (Uhler). The four Cicadellids used in experiment R were identified without magnification as *Endria inimica* (Say).

[2] All of the numbers used to indicate the numbers of insects used in each experiment were approximations except in the cases of experiments R, L3-10 and L15-4.

Table 8. Representative samples of Cicadellidae from collections used in the transmission experiments C, F, M, and R, listed in table 7.

Species of Cicadellidae	Identification mark and date of collection			
	F Sep. 27	C Oct. 4	R Oct. 20	M October
Macrosteles divisus (Uhler)	40	13	2	55
Endria inimica (Say)	11	10	8	36
Exitianus exitiosus (Uhler)	3	2	2	9
Deltocephalus sonorus Ball	0	0	3	12
Deltocephalus flavicosta (Stal.)	0	0	0	2
Aceratagallia uhleri (Van D.)	0	0	0	7
Draeculacephala sp.	0	1	2	6
Neokolla hieroglyphica (Say)	0	1	0	1
Nesosteles neglectus (Del. & Dav.)	0	1	0	1
Psammotettix striatus (L.)	0	0	0	1
Balclutha sp.	0	0	1	2
Empoasca sp.	0	0	1	1
Pharaphlepsius irroratus (Say)	0	1	0	2
Macrosteles sp.	0	0	0	2
Totals	54	29	19	138

Individual Insects Caged on Individual Wheat Plants.

The names of the insects and the number of experiments tried with each is given in Table 10. The various combinations of time in days that the more common species of leafhoppers were allowed to feed on infected and healthy plants in these experiments is shown by Table 9. The procedure for these experiments is described on page 17.

A total of 280 separate experiments with at least 10 different species of leafhoppers, and 12 additional experiments with other insects had been completed by July 7, 1951.

Some of the plants developed symptoms that appeared similar to those caused by the mosaic virus. Inoculum was prepared from 29 of these plants and inoculated to healthy plants, but none of these were found to have mosaic. Possibly the symptoms observed were caused by a nutritional deficiency or perhaps a reaction to the feeding of the leafhopper used in the experiments.

In the first 74 experiments the leafhoppers were caged on the individual plants on November 28, 1950. About two weeks later, on December 13, 1950, 48 of these insects were still alive and were transferred to a new set of healthy plants. On January 12, 1951 36 of the original 74 leafhoppers were still alive. This procedure was designed to give some indication of the incubation period of the virus in the insect, if one existed. No transmission of the virus occured, but it did show something of the viability of the leafhoppers under the conditions of the experiments.

Table 9. Various combinations of time in days on infected and healthy wheat plants for the common species of Cicadellidae used in the transmission experiments involving individual insects caged on individual wheat plants,

Cicadellidae

Macrosteles divisus

Infected Plant	8	4	65	65	77	77	78	78	44	44	44	1
Healthy Plant	8	8	39	51	39	50	38	26	25	37	45	32

Deltocephalus sonorus Ball

Infected Plant	4	9	10	29	44	4	4	9	10
Healthy Plant	15	13	14	14	6	29	45	45	42

Exitianus exitiosus (Uhler)

Infected Plant	8	4	4	4	9	9	8	8	4	9	9	9	9	10	4	43	43	43	44	1
Healthy Plant	15	8	15	13	6	14	45	29	45	43	27	44	14	14	20	38	26	40	25	32

Psammotettix sp.

Infected Plant	8	4	9	9	4	9	9	9	9	9
Healthy Plant	8	15	6	13	45	27	43	44	14	28

Endria inimica (Say)

Infected Plant	29	4	1	2	4	8	8	8	8	11
Healthy Plant	45	24	21	20	18	22	17	25	25	12

Table 10. A compilation of the transmission experiments involving individual insects caged on individual wheat plants.

Group	Species	No. of experiments
Cicadellidae	*Macrosteles divisus* (Uhler)	85
Cicadellidae	*Psammotettix* sp.	47
Cicadellidae	*Psammotettix striatus* (L.)	1
Cicadellidae	*Exitianus exitiosus* (Uhler)	41
Cicadellidae	*Endria inimica* (Say)	28
Cicadellidae	*Deltocephalus sonorus* Ball	12
Cicadellidae	*Aceratagallia uhleri* (Van D.)	1
Cicadellidae	*Nesosteles* sp.	8
Cicadellidae	*Empoasca* sp.	2
Cicadellidae Agalliini	Unknown	17
Cicadellidae	Unknown	38
Coredae	*Aufeius impressicollis* Stal.	1
Delphacidae	*Delphacodes propinqua* (Fieb.)	1
Delphacidae	Unknown	3
Acrididae	Unknown nymphs	4
Chloropidae	*Meromyza americana* Fitch	3
Total		292

[1] All insects listed by family name only, either escaped from their cages or died and decomposed before they could be identified more specifically. The *Psammotettix* sp. probably were mostly *Psammotettix striatus* (L.). The *Nesosteles* sp. probably were mostly *Nesosteles neglectus* (Del. & D.). None of the *Empoasca* were identified to species. The Agalliini were all probably *Aceratagallia* sp. mostly *Aceratagallia uhleri* (Van D.) and *Aceratagallia longula* (Van D.).

DISCUSSION

The previous work done on the insect transmission of wheat mosaic in the United States is quite scanty. Most of the publications concern work done in Russia with a virus which is probably not closely related to the viruses which cause wheat mosaic in the United States.

Atkinson's (1949) conclusion that the green bug, Toxoptera graminum (Rond.), was a vector of wheat mosaic has not been confirmed by this work, or by that done by Painter and Fellows as mentioned previously. If the green bug is a vector of this virus it must transmit it only under certain conditions not used in these experiments.

The results of this work do not justify naming any specific insect as a vector, at best they offer only more assurance that a vector does exist. There were nine separate experiments in which transmission of the virus occurred. Seven of these positive experiments involved leafhoppers that were not identified to species. All of the experiments in which known species of leafhoppers were used were negative. It seems likely that the species involved in these experiments were responsible for at least some of the transmission of the virus. The conditions of the experiments make more definite conclusions impossible.

No adequate means was provided for insect control in the greenhouse. Since the greenhouse was not screened the plants were exposed to insects from outside all during the warm months.

Even during the winter, between fumigation periods, the plants frequently became infested with aphids, thrips, and mites. Also the soil used in these experiments was not sterilized to prevent the remote possibility of soil-borne infection. In addition to these hazards, there was the possibility that the experimental plants could be accidentally infected as a result of handling or wounding. Under these circumstances it seems that only decidedly consistent results could be regarded as significant.

The consistency that could be noted in the results was that seven of the nine positive experiments involved leafhoppers and that these seven experiments were all initiated between October 6, 1950 and November 15, 1950.

Perhaps the vector is one of the common leafhoppers used in the experiments but it is capable of acting as a vector for only a period of two months or less during the fall. The leafhoppers Endria inimica (Say) was probably the only insect used in one of the positive experiments which took place during October 1950, (see experiment R, page 29), but 48 experiments involving about 750 of these leafhoppers which were made during the spring of 1951 were negative on July 7, 1951. Kunkel (1937) found that Macrosteles divisus (Uhler) did not transmit aster yellows during the summer months because the increased temperature inactivated the virus.

If the vector is active and viruliferous in nature only during October and November, there is a slight possibility that the experimental plants may have been infected by these insects in the unscreened greenhouse. Field observations suggest that in all probability most of the transmission of the virus to wheat in nature occurred during the fall. On the other hand since the disease has not been prevalent in the Eastern part of the state, the simplest explanation is that the insect vector is also not prevalent in Eastern Kansas. The main difference in the insect populations in Eastern and Western Kansas that was shown by the collections was that species of the leafhopper genus Nesosteles, were more common on wheat in Western Kansas. Fourteen experiments in which Nesosteles spp. were used were negative.

Several of the less common species of leafhoppers that were collected on wheat were not tried in experiments with known species of leafhoppers. The possibility remains that one or more of these may have been responsible for the seven cases of transmission.

When it is considered that almost every wheat plant in large fields over wide areas in western Kansas have become infected with the virus, and that all of this transmission must occur within a few months time; it seems almost essential that the vector either be quite abundant on wheat or be an extremely efficient vector or both .

All of the more common leafhoppers and aphids collected on wheat were used in what was thought to be a considerable number of experiments. Evidently it may take many more experiments with larger numbers of insects involved actually to demonstrate transmission. Dickson et. al. (1951) reported that the melon aphid, Aphis gossypii Glover, has an efficiency of 1 in 1,600 in transmitting the citrus quick-decline virus. Considering the great abundance of some species of leafhoppers and aphids on wheat, it is conceivable that they could serve as low efficiency vectors and still bring about 100 per cent infections of the plants in wheat fields.

A vector with an efficiency as low as 1 in 1,600 probably would not readily be discovered by experiments involving small numbers of insects. The total number of Endria inimica (Say) involved in all experiments was only about 750 and this was more than twice that of any other single species of leafhopper.

Probably the best evidence derived from these experiments to support the hypothesis that there is a leafhopper vector for the wheat mosaic virus; was the fact that plants in two different pots, subjected to the same experimental conditions, became infected with the mosaic virus. These two pots (L1-7 and L1-8, page 40) were both placed in the same cage with a large number of leafhoppers and infected plants. It seems unlikely that insects outside of the experiment would have been responsible for the infection in these two particular cases, since only nine known instances of transmission occurred in the hundreds of exposed plants in the greenhouse.

If insects outside of the experiments were responsible for these nine known cases of transmission it is difficult to explain why they transferred the virus only to those plants which had been used in the insect transmission experiments. Hundreds of healthy wheat plants used in other experiments were utilized as checks by being observed for mosaic symptoms. These plants were exposed to the insects in the greenhouse, but none of these plants became infected with the mosaic virus. On a few occasions symptoms similar to mosaic did appear on these plants, but each time when inoculum was prepared from the suspect and inoculated to healthy plants no symptoms developed.

Nevertheless, when it is considered that only one virus is known which has been transmitted by mechanical inoculation and also by leafhoppers, perhaps less consideration should be given to the leafhoppers as possible vectors.

In addition to the seven positive experiments involving leafhoppers, one case of transmission resulted from a greenhouse experiment with the wheat stem maggot, <u>Meromyza</u> <u>americana</u> Fitch, and another from a field cage experiment with the crown or subterranean aphid, <u>Rhopalosiphum</u> <u>subterraneum</u> Mason.

The wheat stem maggot adult, <u>M</u>. <u>americana</u>, has sponging type mouth parts and apparently is poorly equipped to feed on plant tissue. However, some of the animal-feeding Diptera that have sponging type mouth parts are able to lacerate the skin of of their hosts. It is not known if any of the plant-feeding

Diptera feed in this manner. Since this case of transmission occurred during February or March 1951, it was isolated in time from the other positive transmission experiments. Seven other experiments with _M_. _americana_ involving about 90 flies were negative. The abundance and life cycle of this insect seems to fit what might be expected of a vector of wheat mosaic.

The case of transmission in a field cage in which _R_. _subterraneum_ was originally introduced is far from conclusive, since other aphids entered the cage of this experiment. Also in this type of experiment there is probably an increased chance that the healthy plants could become infected by the direct contact of rubbing against plants in the infected row.

Very little is known about the life history of this insect; but it is abundant enough on wheat, especially in the fall, to satisfy this probable requirement of a vector of wheat mosaic. Since it is difficult to rear this aphid in the greenhouse, perhaps some correlation between its abundance in the field and the prevalence of mosaic will be observed.

Considering even the lack of refinement in these experiments, it seems that one deduction can be made. A vector of wheat mosaic was present at Manhattan, Kansas during the fall of 1950.

SUMMARY

This work was an attempt to determine how wheat yellow streak-mosaic virus is transmitted in nature. It seemed likely that some wheat feeding insect served as its vector. One of the first objectives was to prepare a list of insects which live on wheat. This list consisted of various members of ten orders of insects and two families of mites. Since the wheat-feeding aphids were previously well known, emphasis was placed on the leafhoppers. Leafhoppers belonging to 17 different genera were collected, but only about 7 species or groups could be considered as common.

A total of 189 experiments involving approximately 6,178 insects and 292 experiments in which individual insects were used were completed or carried through to the point of observing the experimental plants for symptoms. This involved the utilization of all the field collected insects in as many different types of experiments and different combinations of time and numbers of insects as were possible in a year's work.

Symptoms developed in healthy plants which were used in nine experiments. These symptoms were proved to be caused by the mosaic virus. While it may not have been proved that the transfer of the virus was caused by the insects used in the experiments, it seemed highly probable that the experimental insects were responsible for most of the transmission that occurred.

The insects used in seven of the nine positive experiments were leafhoppers. All seven of these cases of transmission took place between October 6, 1950 and November 15, 1950. The specific identification of the leafhoppers used in these experiments is not definitely known, but probably the only leafhoppers used in one of the experiments was Endria inimica (Say).

In addition to the seven positive experiments involving leafhoppers, one case of transmission resulted from a greenhouse experiment with the wheat stem maggot, Meromyza americana Fitch and another from a field experiment with the crown or subterranean aphid, Rhopalosiphum subterraneum Mason. The conditions and time of transmission in these two experiments made it seem more likely that accidental transmission occurred here than in those experiments involving leafhoppers. It will be necessary to use these two species of insects in more experiments before their ability to transmit the virus can be determined.

This work indicated that the vector or vectors of wheat yellow streak-mosaic virus was present at Manhattan, Kansas, during the fall of 1950, and that the vector is most likely a leafhopper.

ACKNOWLEDGMENTS

The writer expresses sincere appreciation to Drs. R. H. Painter and Hurley Fellows for their suggestions and guidance in this work, and acknowledgment of their direct help both in the carrying out of these experiments and in the final preparation of this thesis.

Thanks are due Dr. Roger C. Smith, Head, Department of Entomology, for his interest and encouragement in the work and for his reading of the tentative copy of this thesis.

Acknowledgment is made to Professor L. E. Melchers, Head, Department of Botany, and Dr. E. D. Hansing for their suggestions and interest in the problem.

Indebtedness is acknowledged to the following men for the identification of insects and mites: R. H. Beamer, Cicadellidae and Fulgoroidea; J. B. Kring, Aphididae; S. F. Bailey, Thysanoptera; and C. F. W. Muesebeck and staff of the Bureau of Entomology and Plant Quarantine, various groups of insects and mites.

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TRANSMISSION EXPERIMENTS INVOLVING POSSIBLE INSECT VECTORS OF THE VIRUS, MARMOR VIRGATUM VAR. TYPICUM McKINNEY, WHICH CAUSES WHEAT YELLOW STREAK-MOSAIC

by

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B. S., Kansas State College
of Agriculture and Applied Science, 1950

ABSTRACT OF THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology

and

Department of Botany and Plant Pathology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1951

Wheat yellow streak-mosaic virus has recently been recognized as an important factor in the production of wheat in the western one-third of Kansas and near by states. The purpose of this work was to determine how the virus is transmitted in the field.

Soil and seed borne transmission had been considered and rejected in early publications. Since the possibility of insect transmission had not been given adequate attention, it seemed important to study the wheat-feeding insects as possible vectors of the virus.

A list of insects and mites found on wheat was prepared from collections. This list included various members of ten orders of insects and two families of mites. Particular attention was given to those insects which have piercing and sucking type mouth parts. The wheat-feeding aphids had been previously studied; therefore, emphasis was given to the leafhoppers. Leafhoppers belonging to 17 different genera were collected. The following seven species or groups were the most common leafhoppers taken in the collections: Macrosteles divisus (Uhler), Exitianus exitiosus (Uhler), Endria inimica (Say), Nesosteles spp., Psammotettix spp., Deltocephalus spp., and Agalliini including Aceratagallia spp.

All of the field collected insects were utilized in as many different experiments and under as many different conditions as possible in a year's work. There were several types of experiments, but in each type insects were exposed to diseased and healthy plants either simultaneously or alternately. The healthy plants were then observed for symptoms.

A total of 189 experiments involving approximately 6,178 insects and 292 experiments in which individual insects were used were completed or carried through to the point of observing the experimental plants for symptoms. This made up a combined total of 481 experiments and 389 of these involved leafhoppers.

Symptoms, later proved to be caused by the mosaic virus, developed in healthy plants which were used in nine experiments. While it may not have been proved that the transfer of the virus was caused by the insects used in the experiments, it seemed probable that the experimental insects were responsible for most of the transmission that occurred.

The insects used in seven of the nine positive experiments were leafhoppers. All seven of these cases of transmission took place between October 6, 1950 and November 15, 1950. The specific identification of the leafhoppers used in these experiments is not definitely known, but probably the only leafhoppers used in one of the experiments was Endria inimica (Say).

In addition to the seven positive experiments involving leafhoppers, one case of transmission resulted from a greenhouse experiment with the wheat stem maggot, Meromyza americana Fitch, and another from a field experiment with the crown or subterranean aphid, Rhopalosiphum subterraneum Mason. It will be necessary to use these two insects in more experiments before their ability to transmit the virus can be determined.

This work indicated that the vector or vectors of wheat yellow streak-mosaic virus was present at Manhattan, Kansas, during the fall of 1950, and that the vector is probably a leafhopper.